Behavioral Modeling for Science & Energy Policy

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"When we try to pick out anything by itself, we find it hitched to everything else in the Universe."

John Muir, ***My First Summer in the Sierra*** **(Boston: Houghton Mifflin, 1911)**

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Contents

- Behavior in general
- Specific challenges for basic science
- Way forward

Behavior in the Real World

- Experts fail to forecast
- Markets boom and bust
- Policy instruments fail to achieve expectations
- Large firms fail with little warning
- Change is crisis-driven rather than controlled
- New technologies are implemented during depressions
- Organizational structures resist change: bosses, hierarchies, bureaucrats

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Behavior in Dynamic Decision Making Experiments

- As the dynamic complexity of a system grows (as there are more time delays, feedbacks (especially positive feedbacks), accumulations (stock and flow structures) and nonlinearities, human performance worsens, and learning slows
- Decision makers seldom plan or implement their plans
- Dynamic complexity induces market overshoot and oscillation (Kampmann 1992)
- Hill climbing is difficult in simple resource systems, leading to collapse even when property rights are explicit (Moxnes 1998)
- Mental models of climate change violate conservation of matter (Sterman & Booth Sweeney 2002)

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Behavior in The Majority of Climate Policy Models

- Equilibrium is assumed rather than emergent
- Market outcomes reflect agent preferences
- Agents perceive and respond to prices instantaneously, and may even know the future
- Agents have sufficient structural knowledge to respond appropriately to changes in their environment
- There are few if any externalities other than climate
- Risk is absent

Slide 6

TF7 There has been progress in bottom-up elements of large scale models, but the realm of compact models remains neoclassical.
Tom Fiddaman, 6/26/2007

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Consequences of Neglecting Behavior

- **Part of the observed inflexibility of the energy-economy system is behavioral; if it is instead ascribed to technology,**
  - estimates of the welfare consequences of changes in allocations are biased
  - the potential for institutional and informational policies is understated
- **Revealed preferences are suspect**
  - utility functions that justify observed savings and income distribution are unfair to future generations and today's poor
- **Idealized policy instruments won't deliver in the real world**

TF8

Slide 7

TF8 Lock in?

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Representing Behavior

(FREE)
Hill Climbing
Adaptive-
Extrapolative
Expectations

Hill Climbing
Adaptive
Expectations

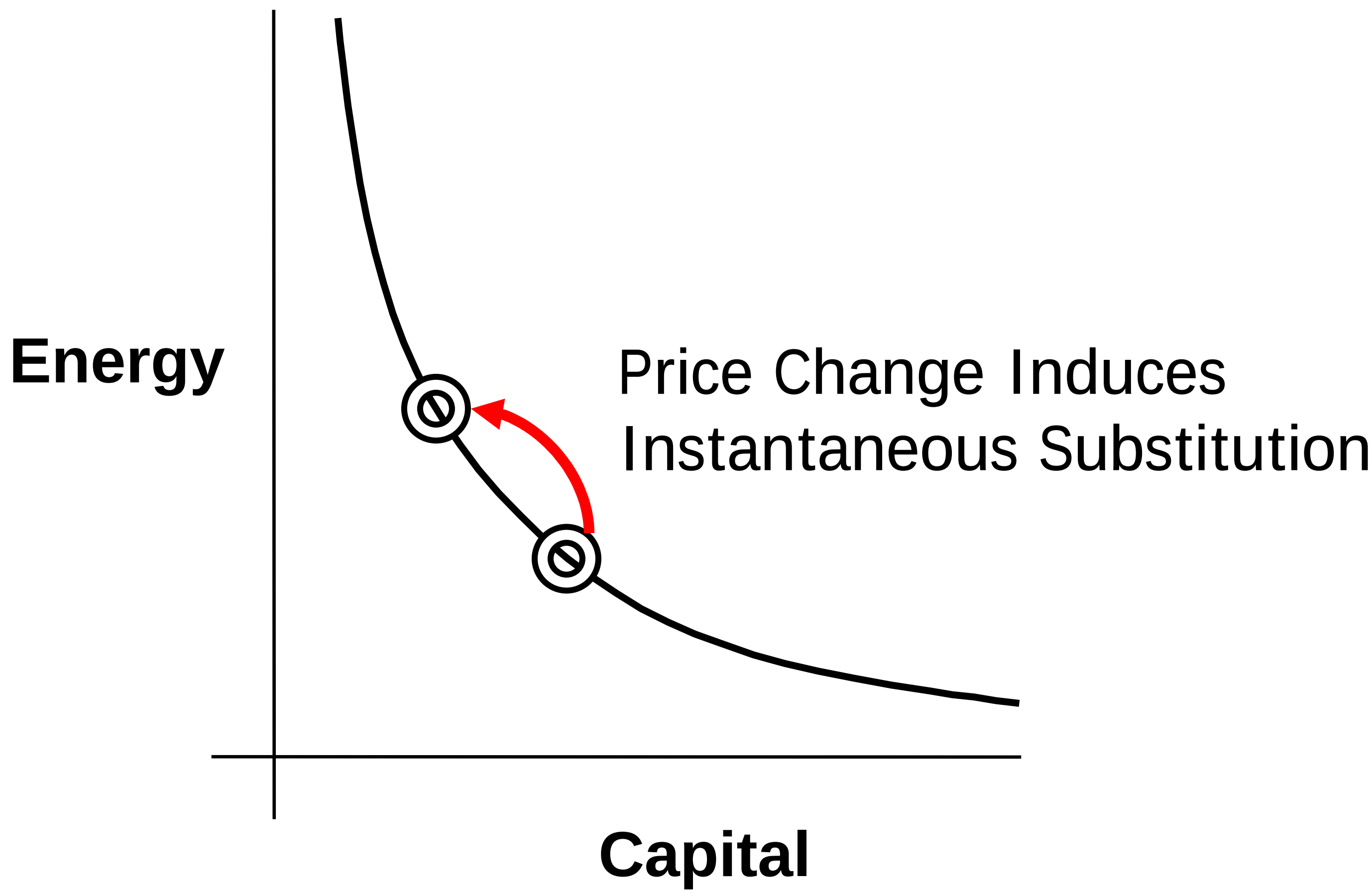
Population
Learning
(ABM)

Stochastic
Optimal

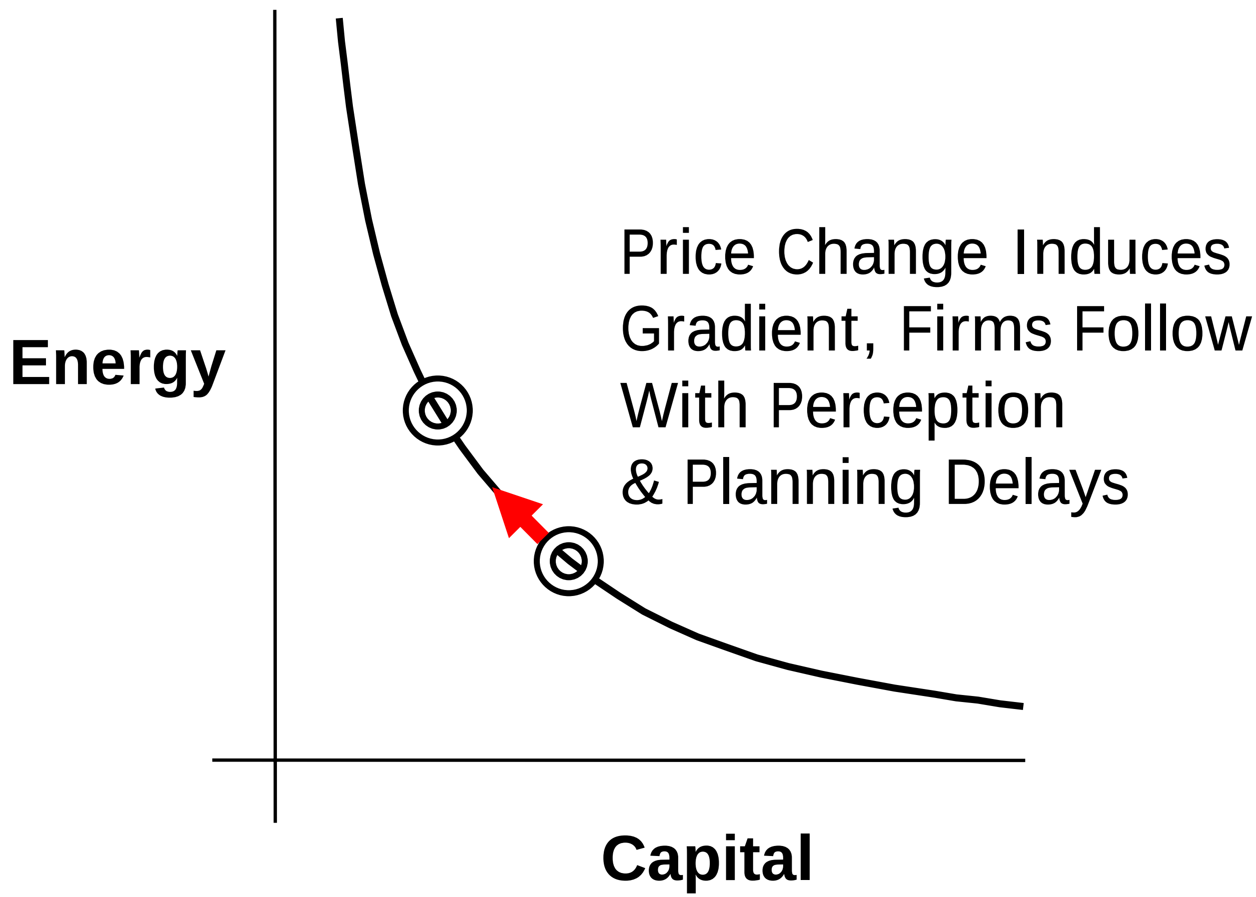
Intertemporal
Optimal
(DICE)

Myopic
Optimal
(CGE)

Production Technology



Production Technology



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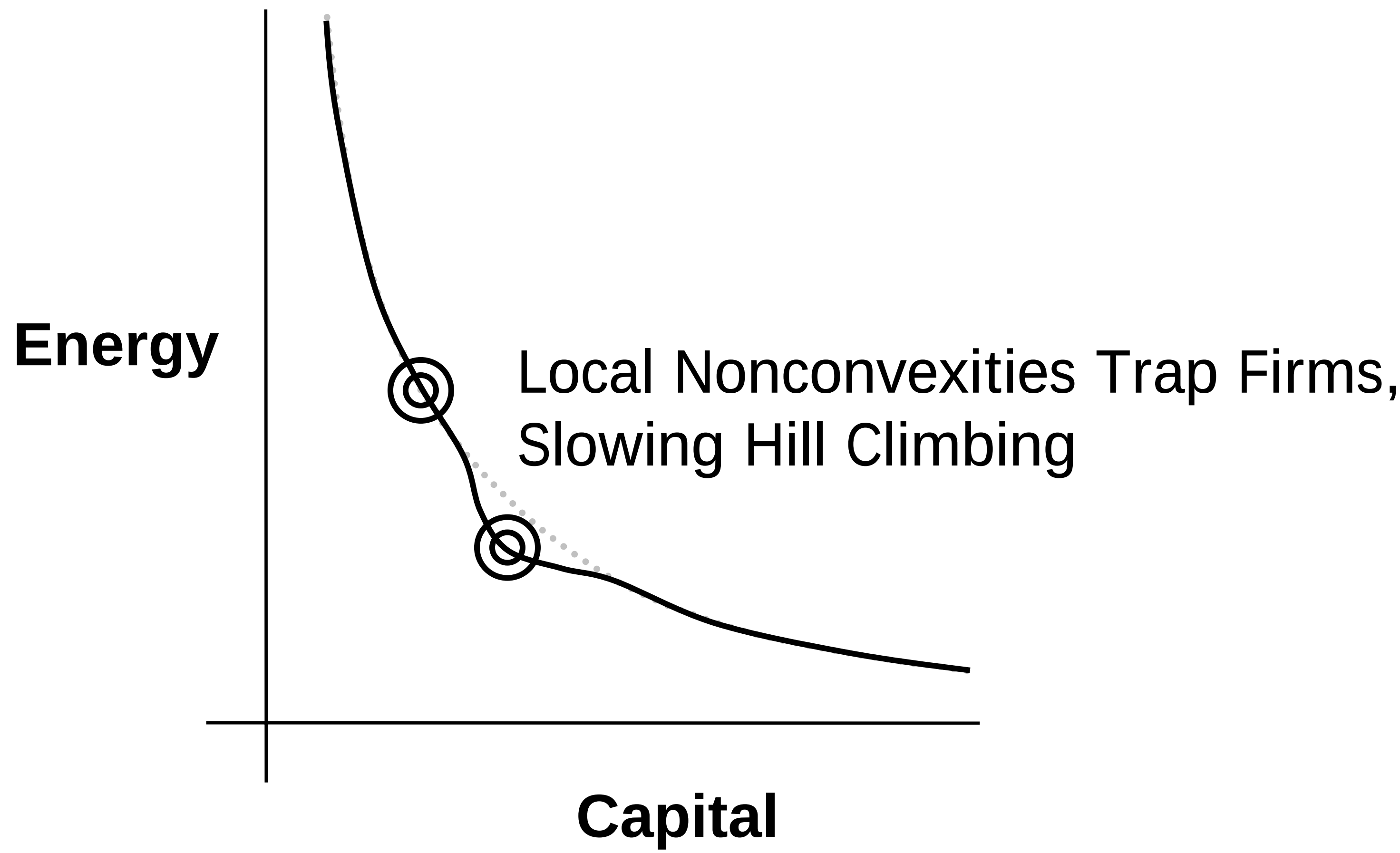

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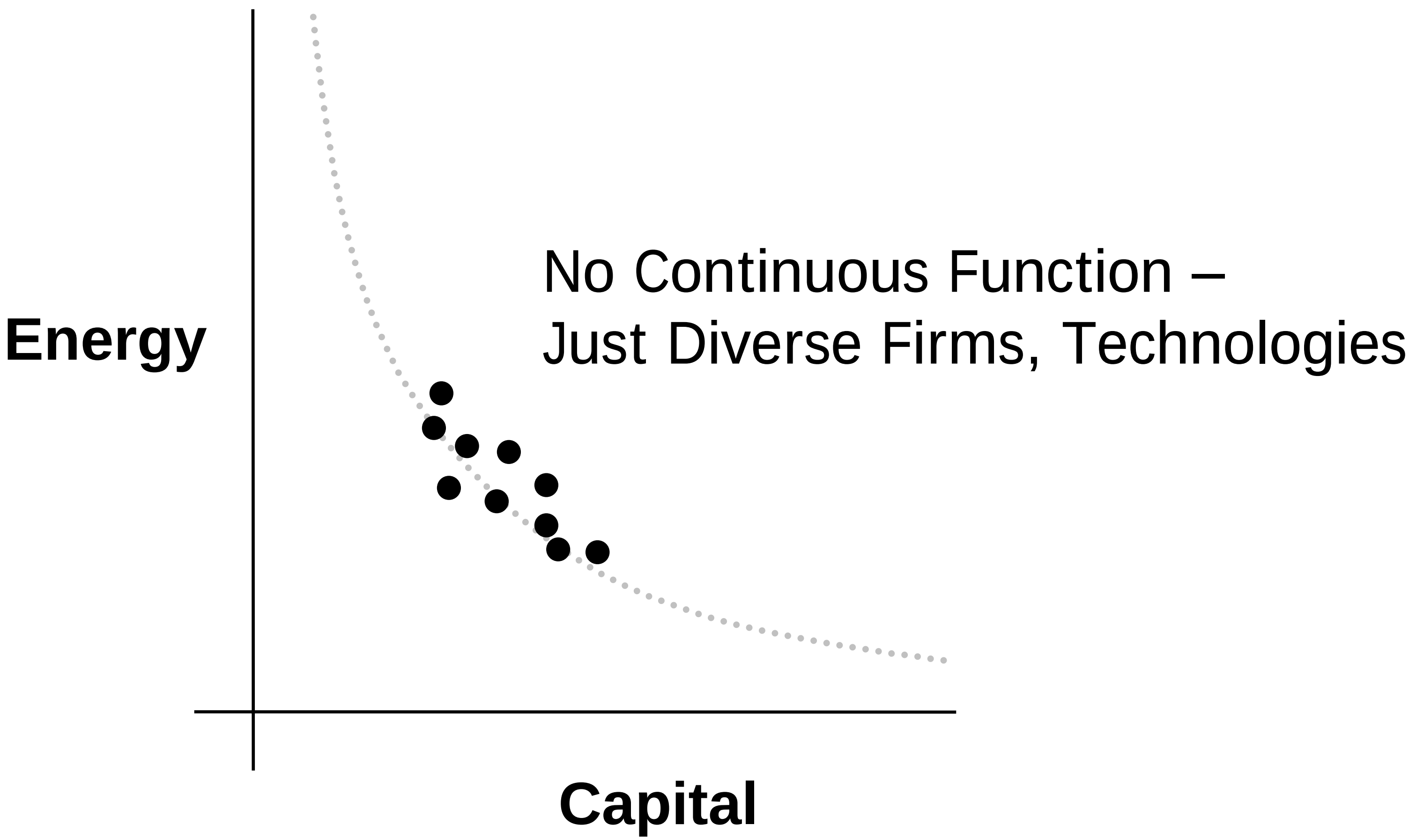

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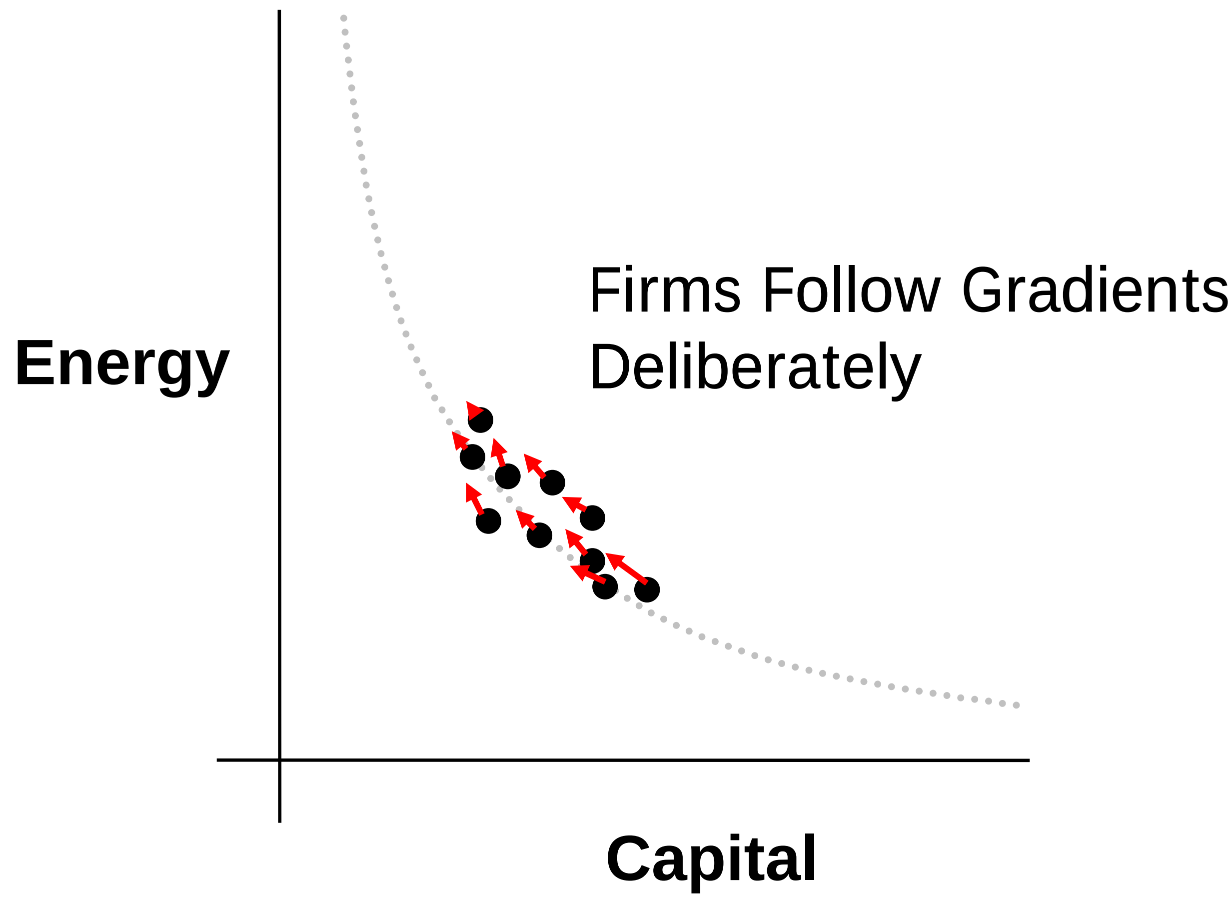

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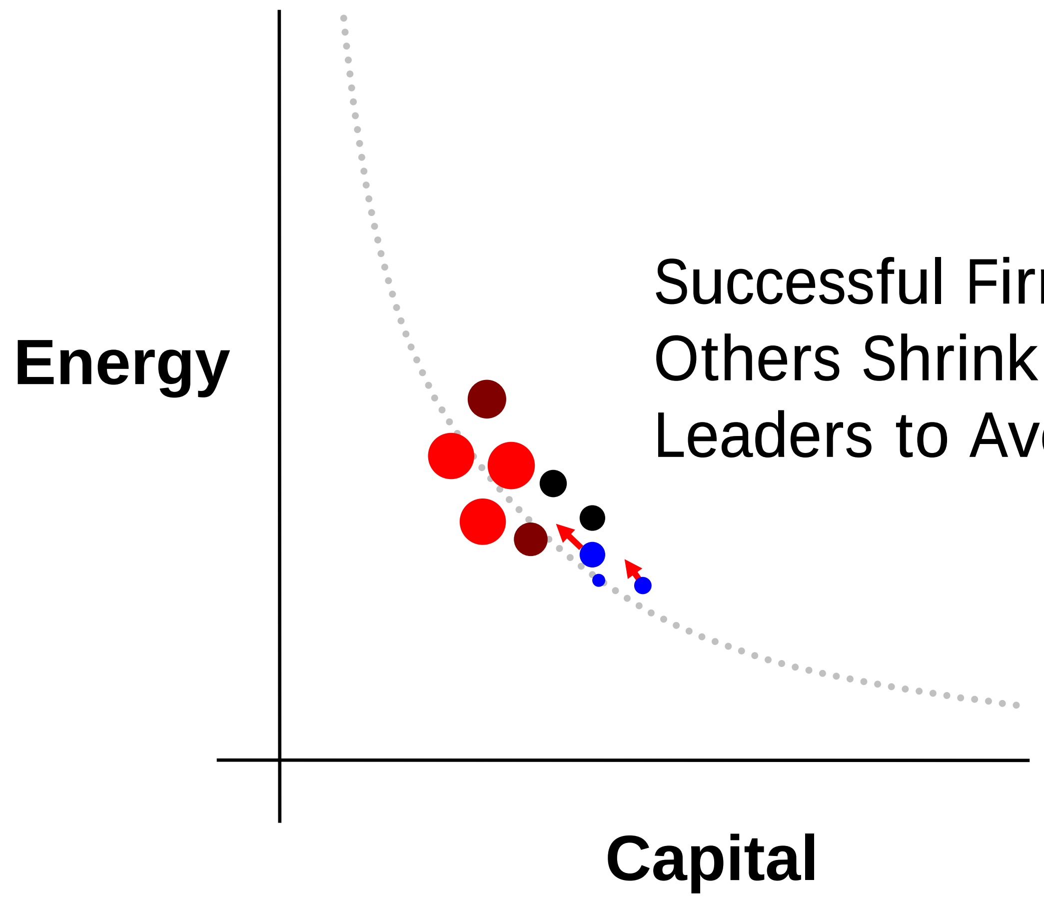

Successful Firms Grow; Others Shrink, and Imitate Leaders to Avoid Failure

Micro Foundations of Macro Behavior

- At the most behavioral level of description, it's possible to see *really* bottom-up emergence of macro phenomena

But...

- Many more firm structures and parameters to specify
- Slower model execution
- Cumbersome calibration to data
- Inventories needed to buffer non-clearing markets
- Difficult to represent detail (e.g. sectors) in a recognizable way

Static vs. Dynamic Tasks

- **Factor allocation is dynamically fairly simple (obvious gradient, quick feedback on performance)**
- **Other problem domains are dynamically complex**
  - Intertemporal allocations
  - Large project management
  - Networks
  - Preferences
  - ***R&D***
- **In dynamically complex environments, the system is likely to evolve faster than equilibrium can emerge**

Energy Meets Science Policy: Endogenous Technology

- **Lots of progress**
  - Implementation of learning curves and deliberate R&D
- **Some progress**
  - Diffusion and adoption dynamics
  - Human capital measurement
  - Normative R&D policy
- **Limited progress on other fronts**
  - Spillovers, particularly across disciplines
  - Cannibalization and crowding of funding
  - Operational explanation of learning
  - Behavioral R&D policy

Portfolio Evaluation

- **Technologies interact in important ways**
  - Some useful outcomes (e.g. H2 economy) require multiple coordinated successes
  - Other technologies represent redundant approaches to the same problem
  - Research projects have precedence relationships and compete for limited resources
  - Knowledge spillovers cross technology stovepipes
- **Some technologies have little value until complementary policies (markets, taxes, regulations) support them**
- **Much of the value of a technology is due to provision of non-market amenities or hedges against contingencies**
- **Research program support can be dynamically adjusted as new information arrives**

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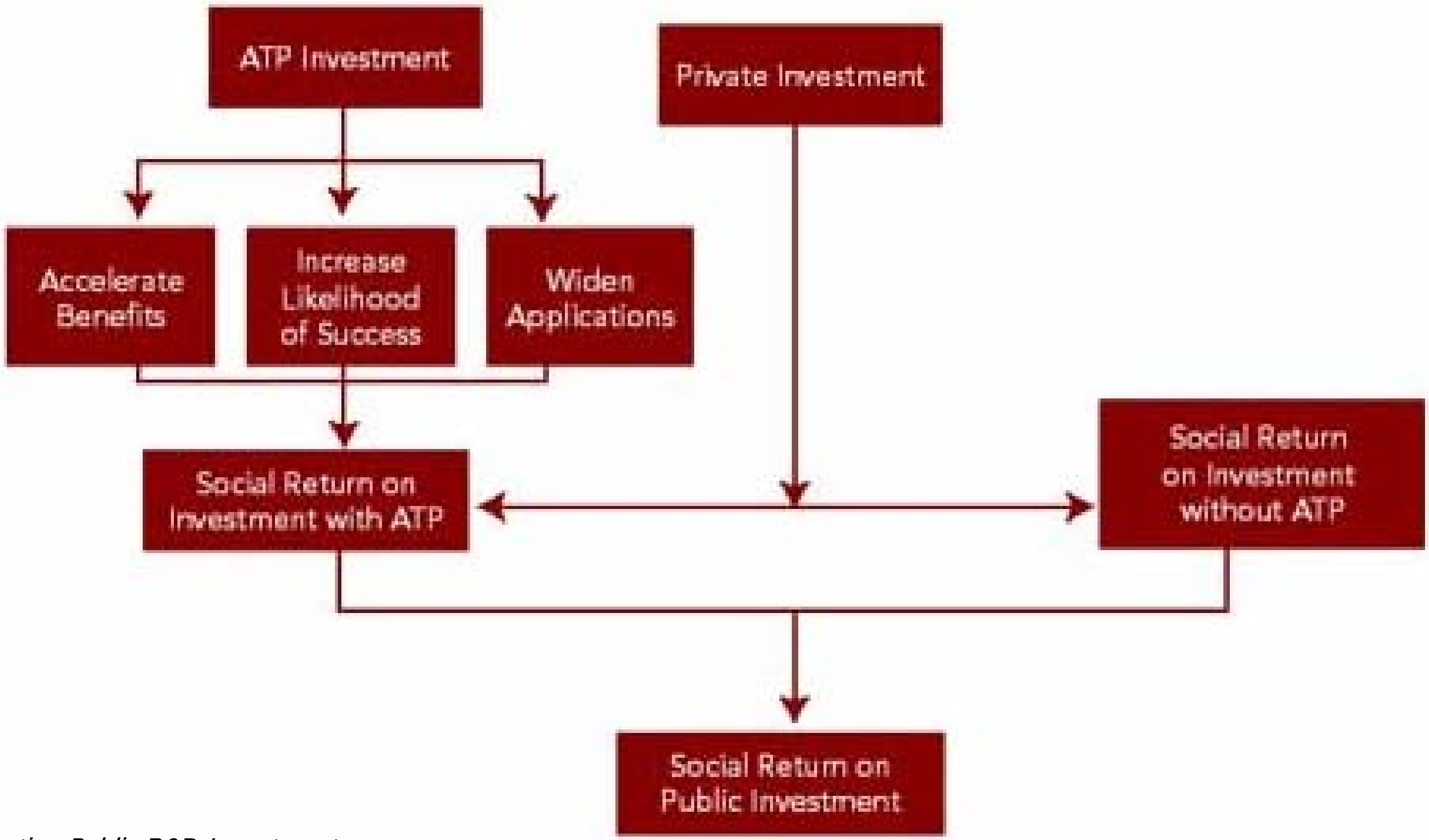
Figure 6–1. Elements Determining Social Return on Public Investment and Social Return on Investment



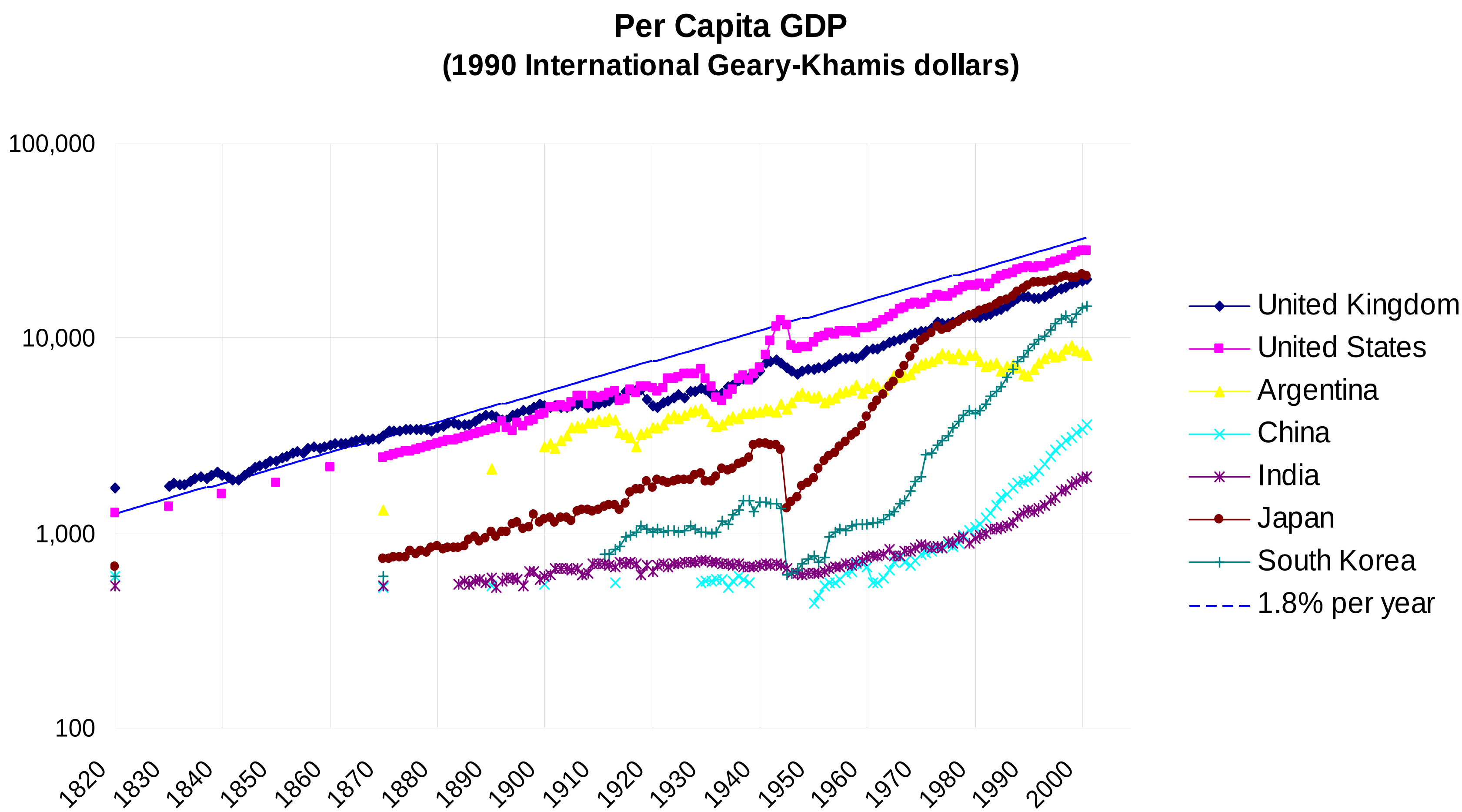
A Toolkit for Evaluating Public R&D Investment Models, Methods, and Findings from ATP's First Decade Rosalie Ruegg, Irwin Feller July 2003

The Unique Challenge in Basic Science

- **The menu is unknown**
  - What technologies will be relevant in 50 years?
  - What spillovers will current science have on the economy?
- **The appetite is unknown**
  - What strategic threats will emerge?
  - What will we want? (What is the economy for?)

- **Two approaches:**
  - Pretend we know and do lots of Monte Carlo simulation
  - Search for generic strategies that work regardless of the agenda

The economic growth of nations



A Way Forward

Model Typologies

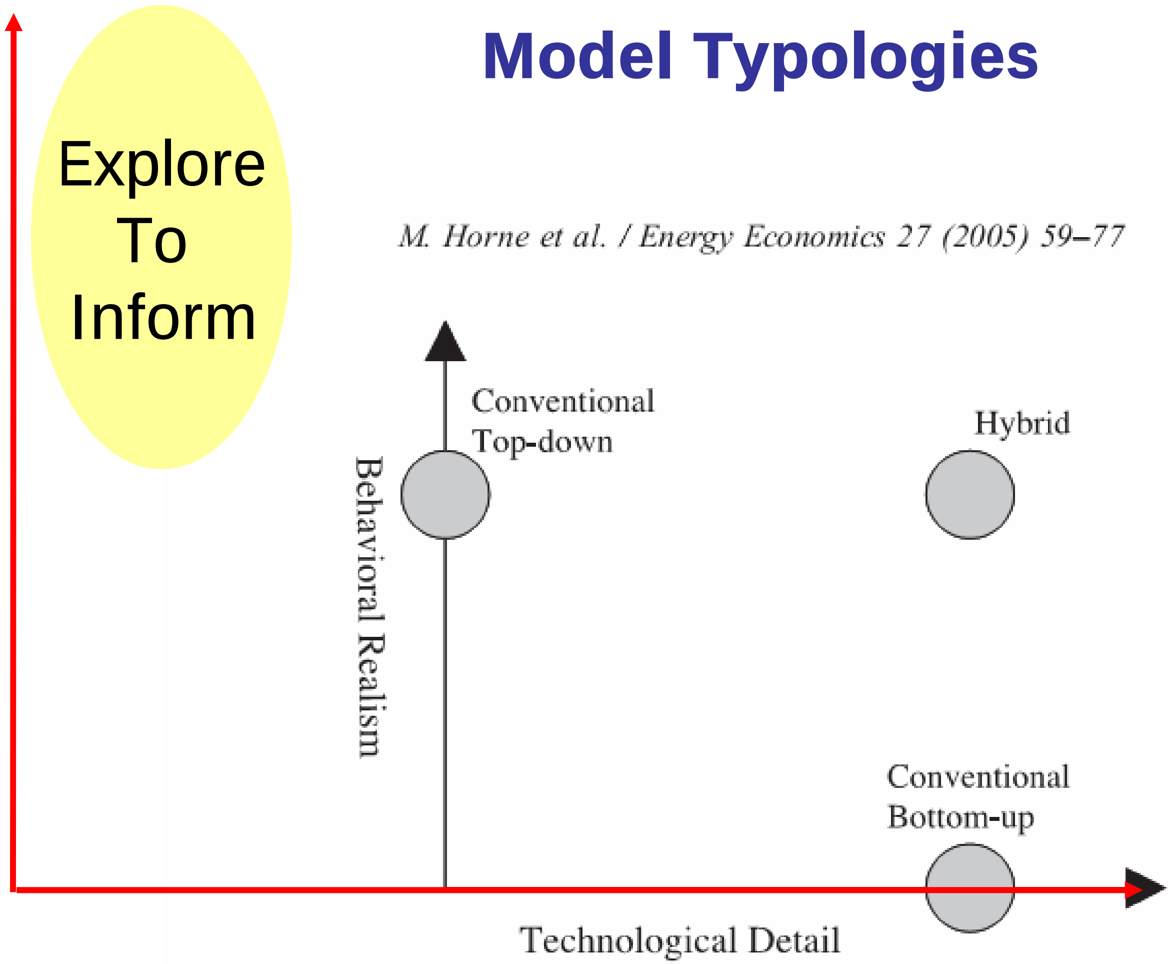


Fig. 1. Energy-economy model typologies (adopted from Jaccard et al., 2003).

A Hierarchy of Models and Questions

Priorities, Allocations

National Research Policy

What share of GDP should be R&D?
Should that share be induced by grant, tax, subsidy, regulation, ... ?

Portfolio

How do program activities roll up to aggregate mission?

Program Management

How do program $ create research inputs?
What production function turns inputs into research outputs?

Lab Monitoring

How can labs be monitored and managed using limited data?

Large Project Management

How can overruns and failures be detected early?

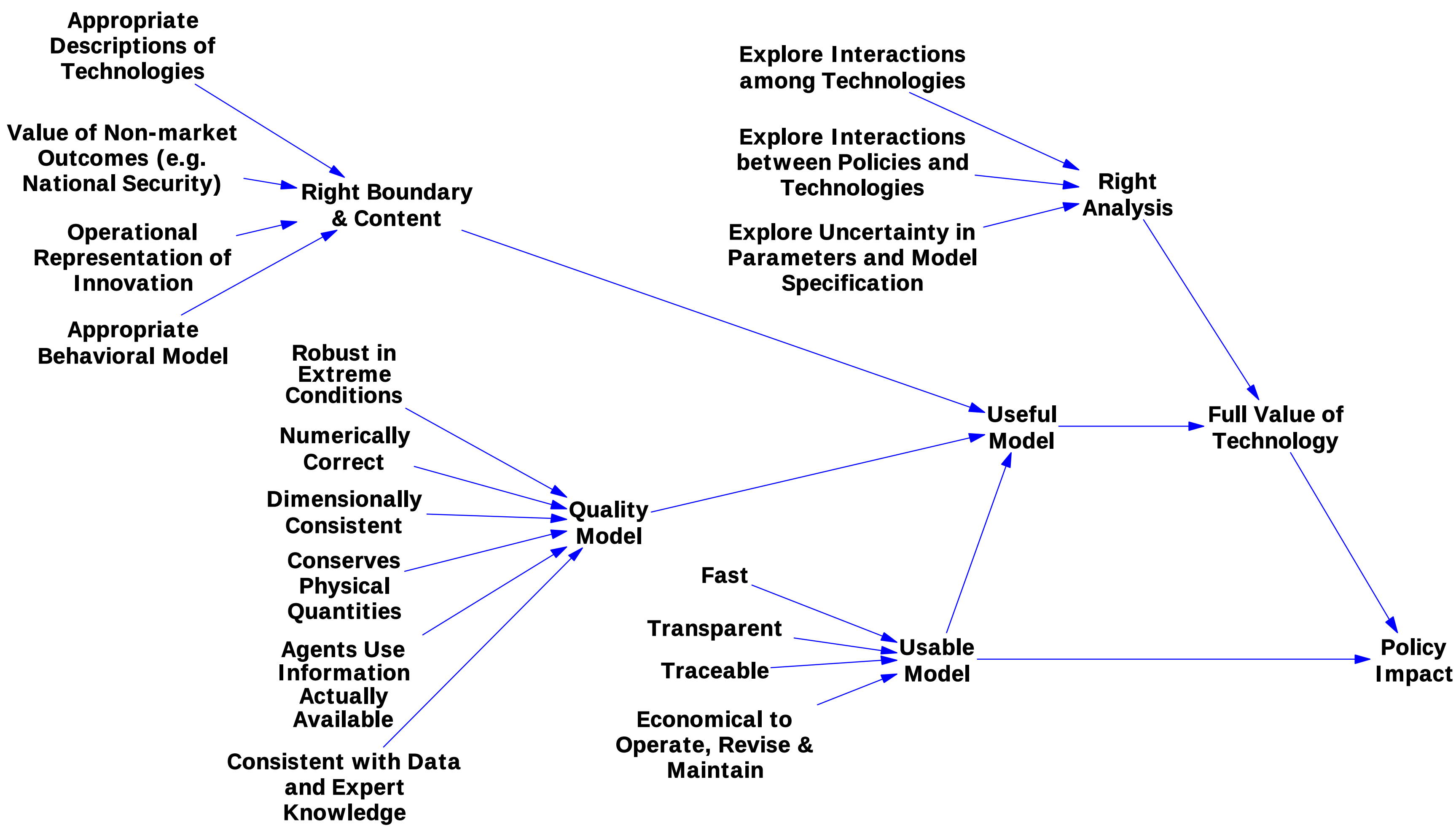
Project Portfolio Risk

What is the right risk/return mix?
When should projects be added, off-ramped?

...

Reporting

Balanced Mix of Critical Elements



Broad Mix of Disciplines

- Evaluation research
- Psychology
- Org Sci
- Management Sci
- Marketing
- ABM / Complexity
- Economics

Principles for Modeling Behavior

- **The inputs to all decision rules must be restricted to information actually available to real decision makers.**
  - Expectations about the future are based on historical information and may therefore be incorrect.
  - Actual conditions and perceived conditions differ due to measurement and reporting delays and conflicting prior beliefs.
  - The outcomes of untried contingencies are not known.
- **The decision rules of a model should conform to managerial practice.**
  - All variables and relationships should have real world counterparts and meaning.
  - Units of measure must balance without the use of arbitrary scaling factors.
  - Decision making should not be assumed to conform to any prior theory but should be investigated firsthand.
- **Desired and actual conditions should be distinguished. Physical constraints to the realization of desired outcomes must be represented.**
  - Desired and actual states should be distinguished.
  - Desired and actual rates of change should be distinguished.
- **Decision rules should be robust under extreme conditions.**
- **Equilibrium should not be assumed. Equilibrium and stability may (or may not) emerge from the interaction of the elements of the system.**

Adapted from Sterman (2000)

Three Challenges

- **Bottom-up foundations for top-down models: how to develop global model structures consistent with aggregates of populations of realistic firms?**
- **Communication: how to maintain transparency and usability when doing things right implies more structure?**
- **Productivity:**
  - Faster model building
  - Efficient federation of models
  - Use of data
  - Automation of robustness checks
  - Exploration and visualization

Examples – Behavioral Models

- ETM (Sterman)
- MADIAM (Weber)
- FREE (Fiddaman)
- China Coal (Ventana for NETL)
- E3 (Ventana for DOE SC)